SERIAL BUS UTILIZATION FOR SMART METERS IN HOME AREA NETWORK

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Abstract: This paper focuses on possibilities of using data from smart meters for home area network applications. Data communication between a smart meter and a consumer for home area network can be done directly witout dedicated communication channel for remote data acquisition. The serial interface can be used for user data readout, depending on the support of the meters. This paper demonstrates experimental measurements of RS-485 serial bus, with the main objective to find a comparison of different bus configurations and different distances. The main contribution is recommendation of the best RS-485 setup of resistors configuration for home area networks.

Keywords: smart grid, smart meter, RS-485, measurement, BER, home area network

1 INTRODUCTION

Smart grid is a term for systems and applications for real-time management of production and consumption of e.g. water, gas or electrical energy. In the case of electrical energy and smart metering, it is the smart electrical grid. Standard dedicated communication with smart meters is between the central station of the energy distributor (SCADA) and the smart meters (tens to hundreds of meters) in supply points through gateway (or data concentrator) located in the transformer station. On the other side, smart meter allows also communication to consumer via serial bus interface. The smart grid allows scheduled a smart meter readout every hour or less (every 15 minutes or 1 minute), but it is also possible to use this data for consumer. There are applications to monitor power consumption in a smart home system, where the consumer uses a measuring equipment with some inaccuracy ascompared woth the smart meter. Each of these systems is designed to reduce charges. From the energy distributor point of view, it is a significat problem to determine the optimal amount of energy needed to be delivered to the consumer, thus load forecasting. This issue is described in paper [1], where the artificial neural network is considered for smart meters data processing in AMI.

The smart grid idea has opened opportunities for the consumer and its own use of data directly within the home area network as it provides the same consumption data that is subsequently used for billing by the energy distributor. Using the data directly from the smart meter allows using the valuable energy which is generated at house before exporting the excess back to the grid. The self-consumption, which is important e.g. to the solar energy user since the electricity sold back to the grid is only a fraction of its worth, and it is more economical to use that part of energy while it is still in the home area. Smart meter only cannot identify how much power the solar system is generating. The next step can be the use of an external monitoring system to manage the amount of energy generated by thesolar system from the total energy consumed. This area of consumer use of smart meter data is still in gradual evolution. For this type of application, basic requirements must be met to use and support the communication protocol standard: Two-way communication and simple communication interface. The highly supported interface is the RS-485 serial bus [2], which is the object of experimental measurements. Purpose of these measurements is to specify the basic requirements of error-free communication for consumer applications. Acquired results recommend appropriate configuration of the impedance matching RS-485 line for home are netwrok.

2 EXPERIMENTAL MEASUREMENT

The suitability verification of the RS-485 serial bus for use in smart meter readouts or other applications was verified and experimental measurements have been made that are based on IEC (ČSN EN) 62056-21 requirements [3]. The application protocol DLMC/COSEM [4], [5] is considered, the data format and amount of data used for testing was customized for the protocol.

2.1 MEASUREMENT SETUP

A workspace was created, whose aim was to enable serial communication over two lines. Using any eight-wire cable we can simultaneously operate e.g. the communication of four two-wire buses.

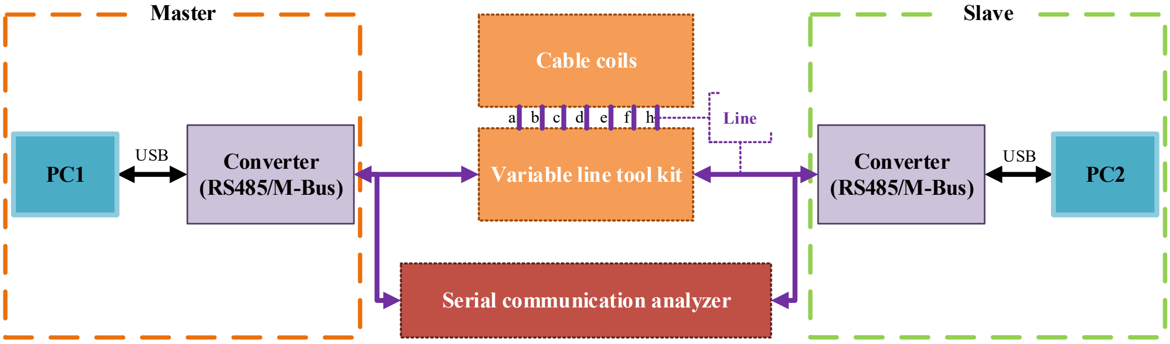


Fig. 1. Connection diagram of the workspace.

Fig. 1 shows the block diagram of workspace connections. The conception of the workspace allows real communication between a meter device (smart meter) and the consumer (own device). Because the master-slave principle is desirable, only one master unit and one slave unit appear in the network, which creates a point-to-point connection. Considering multiple slaves, it is possible to connect four two-wired slaves and one master to the start topology.

Typically, the reading device (consumer device) is always a master (in the case of the deployed DLMS/COSEM, the consumer equipment is in the client mode). Fig. 1 further shows the connection of the USB converter to the bus and the parallel connection of serial communication analyser Lineeye LE-2500. The line length of the analyser connection wires does not exceed 20 cm.

To create any line length as well as line type (cable type), the variable line tool kit (see Fig. 2a) was used. It allows connection of chosen cable type with RJ-45 connector. By switching on a pair of switches, the connected line length is connected to the bus line. There are seven pairs of the switches a-h according to Fig. 1. Each pair has two connectors RJ-45 for one additional length of line. The connectors at the edge of the kit are for connecting the receiver and transmitter units.

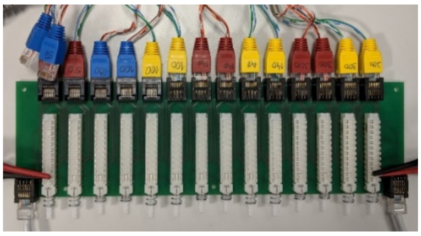
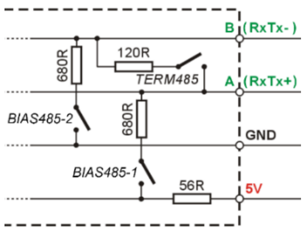
a)  b)  c) 

Fig. 2. Figure of the a) variable line tool kit, b) serial communication analyser LE-2500, c) RS-485 resistors.

Cable type

The cable type used for measurement was the standard network UTP cable by category 3. which contains four unshielded twisted pairs of wires. One pair of the cable always defines half-duplex communication lines of the RS-485 serial bus. In the example a signal ground wire can be additionally connected to a free wire within a single topology. This creates the correct serial line.

3 METHODOLOGY OF MEASUREMENTS AND RESULTS

Two series of measurement were provided. The first series show effect of the line length on electrical parameters of the transmitted data. The monitored variable is the voltage drop according to distance. Second series of measurements show Bit Error Rate (BER) under defined line length, baudrate and data format. BER is monitored according to resistors configuration on both sides of the line. On the transmission line of the RS-485 bus it is necessary to keep impedance of the communication devices equal to the line impedance. The solution is the termination resistance [6], which is connected between differential communication lines A and B in the immediate vicinity of the RS-485 driver. This araugement prevents reflections on the line from the end of line. Reflections are the reason of the worse quality of received data. The termination resistor is shown in Fig. 2c as TERM485. Fig. 2c also shows additional wiring of the bias resistors marked as BIAS485-1/2. These resistors defines technique fail-safe biasing, to drive all receiver outputs to the defined idle state of a logic high. The fail-safe biasing is solved by pull-up and pull-down resistors connected to the signal wires A and B.

3.1 IMPACT OF THE LINE LENGTH ON ELECTRICAL PARAMETERS

This series of measurements was done to verify the impact of distance on the signal level, therefore the data was transmitted in time domain. Line length in range of values 5 – 1130 meters was varied within the variable line tool kit. The termination resistor of 120 Ω was used on the receiver side.

The generator (Agilent 81150A) was used as the transmitter (master/client) unit with BNC output, where the conductors center was used for transmission wires A and B. The signal ground was taken from the BNC braided shield. Transmission signal was defined by eight, 100 Hz rectangle pulses.The oscilloscope (Agilent DSO6032A) was used as the receiver within differential voltage probe (Agilent N2792A). Termination resistor was connected between signal pins on the oscilloscope. Signal ground was connected to oscilloscope ground.

Results of measurement

Fig. 3a shows received data in time domain for baudrade 38 400 Bd on line length of 5 meters. Fig. 3b shows the same data at the same baudrate with line length of 1 130 meters for the UTP cable.

a) b)

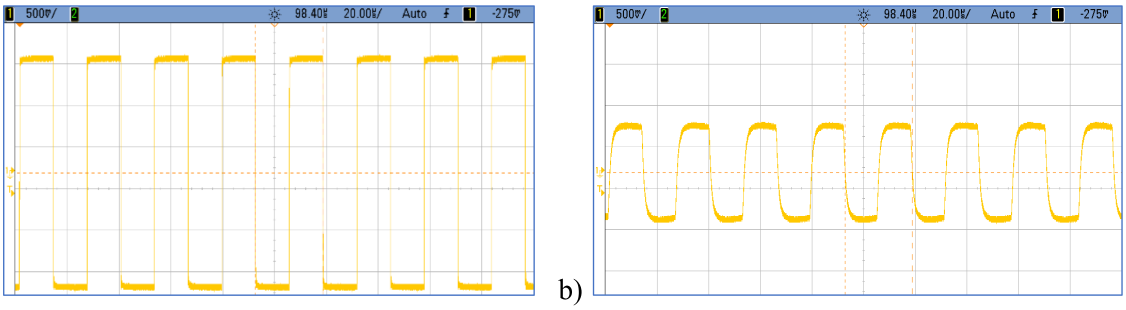


Fig. 3. Oscillograms of the RS-485 communication with 38 400 Bd with distance a) 5 m, b) 1 130 m.

A sufficiently high failsafe-biasing voltage was monitored in each measurement. The minimum of this value is defined to 400 mV [7], [8] and maximum allowed jitter less than 5 % according to specification TIA-RS-485-A [7], [9]. None of the results exceeded the limit values. The resulting deviations are caused by inaccuracy impedance matching (100 Ω instead of 120 Ω). However, due to the application under consideration of this variance is negligible.

3.2 IMPACT OF THE TERMINATION AND BIAS RESISTORS CONFIGURATION ON BIT ERROR RATIO

There is no rule that every device with the RS-485 interface has an implemented termination resistor, because the device may not be located on the end of the line and in such a case the termination resistor must not be placed. Choosing the exact value of the termination resistors according to line impedance is the ideal scenario. Because it is not possible to apply the exact value of the termination resistor, for real practice, an orientation value is determined, which is universally derived from the type of conduction to 120 Ω. The value of the bias resistor is chosen to 680 Ω. The nominal impedance of UTP cable category 3 is determined to 100 Ω, consequently the impedance matching of the measured transmission line is approximately satisfied. Resistors values correspond to wiring of the SB485/USB converter [10] according to Fig. 2c. This converter was used for resistor setup of the serial analyser LE-2500.

Results of measurement

In the scenario, possible cases of configuring both types of resistors to define the idle state is defined in the Table 1. The table describes full configuration for transmitting or receiving node.

Table 1. Definition of possible termination resistor connections and resistor to define idle state on the line.

Configuration name	Connection of termination resistor TERM485 = 120 Ω	Connection of bias resistor 1 BIAS485-1 = 680 Ω	Connection of bias resistor 2 BIAS485-2 = 680 Ω
AllOff	No	No	No
AllOn	Yes	Yes	Yes
AllTerm	Yes – receiver and transmitter	No	No
RxAll	Yes – receiver only	Yes – receiver only	Yes – receiver only
RxBias	No	Yes – receiver only	Yes – receiver only
RxTerm	Yes – receiver only	No	No
TxAll	Yes – transmitter only	Yes – transmitter only	Yes – transmitter only
TxBias	No	Yes – transmitter only	Yes – transmitter only
TxTerm	Yes – transmitter only	No	No

Table 2 shows results of this series of measurements, using serial analyzer LE-2500 and integrated Bit Error Ratio Test (BERT). Test data was created according to pattern data than contains 511 bites of pseudorandom numbers generated by the polynomic function $(x^9 + x^4 + 1)$.

Table 2. Bit error ratio according to resistor configuration on transmission line within 921 600 Bd.

Configuration		**AllOff**		**AllOn**		**AllTerm**		**RxAll**		**RxBias**		**RxTerm**		**TxAll**		**TxBias**		**TxTerm**	
		TX	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**	**RX**	**TX**	**RX**
Term485		X	X	✓	✓	✓	✓	X	✓	X	X	X	✓	✓	X	X	X	✓	X
Bias485-1		X	X	✓	✓	X	X	X	✓	X	✓	X	X	✓	X	✓	X	X	X
Bias485-2		X	X	✓	✓	X	X	X	✓	X	✓	X	X	✓	X	✓	X	X	X
Signal Ground		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Results		**Bit error ratio [-]**																	
Distance [m]	**450**	0.00E+00		0.00E+00		0.00E+00		0.00E+00		0.00E+00		0.00E+00		0.00E+00		0.00E+00		0.00E+00	
	480	0.00E+00		0.00E+00		0.00E+00		0.00E+00		3.56E-04		0.00E+00		1.67E-04		0.00E+00		0.00E+00	
	500	0.00E+00		0.00E+00		0.00E+00		0.00E+00		2.58E-04		0.00E+00		4.86E-02		0.00E+00		0.00E+00	
	550	0.00E+00		0.00E+00		0.00E+00		0.00E+00		1.02E-01		0.00E+00		1.00E-01		2.52E-04		4.95E-02	
	580	9.69E-02		1.11E-04		0.00E+00		0.00E+00		3.80E-01		0.00E+00		1.55E-01		1.04E-01		1.95E-01	
	590	4.85E-03		3.55E-01		0.00E+00		0.00E+00		2.66E-01		0.00E+00		1.43E-01		5.58E-02		5.85E-02	
	600	1.00E-01		4.20E-02		0.00E+00		0.00E+00		3.94E-01		0.00E+00		2.08E-01		1.97E-01		1.57E-01	
	650	1.39E-01		3.18E-01		0.00E+00		0.00E+00		3.86E-01		0.00E+00		2.60E-01		3.13E-01		1.41E-01	
	890	4.19E-01		--		0.00E+00		--		4.19E-01		0.00E+00		4.50E-01		4.41E-01		4.27E-01	
	940	4.62E-01		--		5.31E-04		--		4.89E-01		2.10E-04		4.62E-01		4.29E-01		4.46E-01	
	1030	4.75E-01		--		3.19E-01		--		--		1.16E-01		4.83E-01		4.66E-01		4.78E-01	
	1130	4.97E-01		--		4.12E-01		--		--		4.12E-01		4.83E-01		4.94E-01		5.10E-01	

Table 2 shows all configurations of the resistor connections to transmitter and receiver due to line length. Changes in BER that are caused by attenuation and line reflections can be observed. Table also shows the Signal Ground parameter outside the resistors, which means connected third wire of UTP cable to ground on both sides. In the case of galvanic isolated RS-485 driver, it is recommended to connect the signal ground with isolated signal ground created in the device.

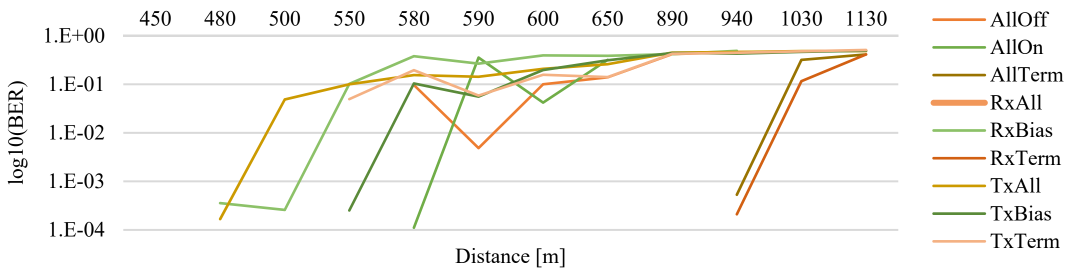


Fig. 4: Bit error ration dependency on the distance.

Fig. 4 shows BER values of all configurations from the Table 2. It can be seen that, with configuration RxAll the zero BER was reached until 650 m which was maximal measured distance for error-free communication. On higher distance synchronization was lost and no further communication was possible. The brown line of he AllTerm configuration shows the recommended connection of the termination resistor, where error-free communication was reached up to 940 meters. The important note of these results is that the RS-485 circuit that is used in the LE-2500 is more than 15 years old.

4 CONCLUSION

Two series of measurements of half-duplex RS-485 serial bus for point-to-point communication using two wires were provided. From the results of all series can be conclude that termination resistor on both sides of the bus allows error-free communication up to 940 meters with 921 600 Bd.

Results from the first measurement confirm all limit values according to specification TIA-RS-485-A. Second measurement demonstrates BER in the distance from 5 to 1130 meters due to termination and bias resistors. All reached values considered unused signal ground. The main goal was verifying the baudrate limit with various configurations of the termination and the bias resistors.

For smart electrical grid applications, it is possible to use this interface, which allows communication of 1 Mbps on the physical layer. With respect to the mentioned applications for a consumer, it is advisable to create new applications that use the RS-485 serial bus.

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